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THE STREAM OF LIFE

BY

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CONTENTS

Chapter I

The Continuity of Life

THE discoveries of biological science during the last hundred years have quite altered our outlook upon many familiar aspects of human life. One of the spheres where the change has been most obvious is in regard to problems of heredity and race. In the old days very little attention was given to such topics; but to-day a new spirit is abroad. Man now realizes that knowledge may make him master of his own fate, and of the future of his race, in ways undreamt-of by his ancestors. Blind acquiescence in destiny is giving place to the hope that destiny may in large measure come to be controlled.

It will be the aim of these talks to give some idea of this change in our thought, and of the facts of biology that bear upon human heredity and human evolution. With that end in view, I shall first endeavour to sketch in the background.

One of the pictures that the study of biology paints for our mental vision is that of the continuity of life—a picture of life as essentially one, a great stream which is in reality single although advancing along myriads of channels; and it is this picture which I want to try to reproduce to-night.

I shall not embark on the difficult task of finding a definition for life, but shall take it for granted as existing. In practice there is no difficulty in distinguishing between things which are alive and things which are not alive, right down to the smallest objects which the microscope can see—that is to say, to minute bacteria only one fifty-thousandth part of an inch in length.

One of the most obvious characteristics of living things is that they reproduce themselves. Not only this, but we now know that every kind of living thing,

from a disease-germ to a turnip or an oak-tree, from a coral polyp to an elephant or an ant, reproduces itself in the same general way: part of the living substance of the parent or parents actually becomes the first beginning of the body of the offspring.

In organisms of the simplest construction—such as the microscopic plants called bacteria, which include most of the disease-germs known—the usual method employed is for the parent to split into two equal offspring, which then grow up and repeat the process. In one sense the parent dies: it loses its individuality by becoming two new individuals. In another sense, however, there is no death, since no corpse is left, but all the parent's living substance is continued into its offspring. This is called reproduction by simple fission or division.

Then many plants and many low types of animal reproduce by budding, which is really nothing but an unequal fission. Every one knows how strawberry plants send out runners, and how at the end of these there grow buds from which new plants arise. A very similar method is seen in such animals as coral polyps.

Finally we come to the method of sexual reproduction. This is almost, but not quite, universally found throughout both plant and animal kingdoms: in plants and lower animals it exists in addition to non-sexual reproduction by fission or by budding, but in almost all higher animals it is the only method of reproduction which is found. One of the great advances of biology was made in the nineteenth century, when the nature of this apparently mysterious process was discovered. It was shown that the essence of sexual reproduction was always the same, whether in a snake or a snapdragon, in a human being or a hen.

Sexual reproduction consists in the fusion, the joining up into one, of two separate bits of living substance which had previously been detached, the one from the body of one parent, the other from that of the other parent. These bits of living substance are cells—units of the same kind as those which go to make up all the living parts of our bodies.

The reproductive cell from the father is called the

sperm, that from the mother the egg or ovum. In all higher animals the two are very different, the sperm being infinitesimal in size but actively moving, the egg relatively much larger but passive and immobile; but none the less both are alive, both are cells, and both have budded off from a part of the parent's body.

Thus all methods of reproduction have this in common —that the offspring, when traced back to its first beginnings, is found to be simply a part of the parent which becomes detached and then grows up on its own account. It is, quite literally, a chip of the old block. Sexual reproduction introduces the complication of there being two parents and two detached bits of living matter, which then fuse; but the continuity of the life-stream is the same. We may put the matter in another way by saying that reproduction is only a special form of growth—the growth of a detached part: it is growth spilling over from the individual to the race.

This continuity is so much taken for granted by biologists to-day that we are apt to forget what very different views used to be held. Up to the eighteenth century it was generally believed that even complicated animals like maggots could be spontaneously generated out of decaying meat, and Virgil was quite convinced that bees could be thus produced out of the carcase of an ox. Samson's riddle about the bees and the lion indicates that the writer of Judges probably held similar views. No sooner had this belief been overthrown for animals large enough to be seen with the naked eye than it was revived with renewed force for the simpler and more minute creatures revealed by the newly-discovered microscope. Only with the patient labours of the great Pasteur in the middle of last century was it finally shown that even so-called "germs" could not be spontaneously generated, and that broth or milk, for instance, would not go bad if the floating spores of bacteria and yeasts were kept from it. Life is not now being generated afresh: it springs always from pre-existing life.

Incidentally, these same researches laid the foundations for aseptic surgery and for the whole science of bacteriology.

Biology thus shows each species of animal or plant

as a stream of one kind of living matter, alternately expanding into pools and contracting into narrows. The pools are represented by the grown-up organisms, the narrows by the comparatively tiny reproductive cells. But the flow goes on continuously.

It is as well to remind ourselves that the idea of flow is only a metaphor, though a very useful one. Another metaphor which has often been used of life is that of the eddy or the whirlpool, which preserves its form while the matter whirling in it is continually being changed. Living matter contains no elements not found in dead matter. An animal is continuously sucking in matter—in food, drink, and air—from the lifeless world outside, accumulating it in itself, building it into the characteristic form of the species, and then restoring it, in its breath and in its excretions, to the lifeless world once more. If, instead of using the metaphor of the stream, we were to say that a living organism was a mill which had the power of utilizing matter not only for its own ends, not only for its own repair, but to generate more mills like itself, we should emphasize this chemical side of the matter more adequately. But the idea of the stream is simpler, and will serve our present purpose.

So far our picture is of a great number of separate streams. But then came Darwin with his famous book, *The Origin of Species.* As I shall show more in detail later, he proved that species could not be eternally fixed, and that the facts of biology demanded evolution as their explanation. The existing kinds of birds, for instance, or of insects, must all have arisen from other species which had existed earlier; and all birds must originally have sprung from one original type of creature, half-bird, half-reptile—all insects from one original primitive insect. This means that all the tens of thousands of separate life-streams that we call the existing species of insects would, if we could trace their history back, be found all to converge to one original source; and the same would be true for all birds, or all frogs, or all fish. When we come to the few main branches of the animal kingdom, such as Vertebrates, Molluscs, or the great division called Arthropods, which includes crustaceans and spiders as well as insects,

then, although direct evidence of their common descent is lacking, the indirect evidences of relationship are more than enough to justify us in extending to them, too, the principle which we must adopt for smaller groups such as birds or fish—the principle of evolution from a common ancestor. To adopt any other theory would be simply to make unnecessary difficulties. We can be reasonably sure, on the basis of all the evidence before us, that animal life started in the single-celled form; that its most advanced members later became many-celled, and reached a simple stage like that seen to-day in polyps; that, later still, different streams branched out in different directions, some becoming worms, some sea-urchins and star-fish, some snails and other molluscs, some insects, spiders, and crabs, and some vertebrates; and that the forefront of the vertebrate stream, ever changing, advanced through the fish-stage to life on land, to warm blood, to greater brain, and so at last to man.

Thus, with the aid of evolution, our picture of life is changed. Instead of many separate streams we see a single flow. This flow advances along the plain of Time through many channels; but all the channels were at one period or another connected, all took their rise in one original source. The qualities of the various streamlets change as they move on in Time, and the sum of these changes represents life's evolutionary progress. When we come to deal with the life-processes of man, it is our first business as biologists to see him in relation to the rest of life, as a single streamlet out of these thousands, and as one in a real sense with the whole continuity of life's moving flow.

CHAPTER II

Heredity

EVERYBODY knows that children on the whole are like their parents; but also that the likeness is never exact. Sometimes a child will be more like an uncle or a grandfather, and sometimes it will seem to show no strong family likeness at all, but to strike out a new line for itself. In the same way, brothers and sisters may show strong family likeness, but (save in the exceptional case of so-called identical twins) they are never exactly alike.

After what I said in my last talk, family likeness is easy to understand. It comes from the fact that children, if you trace them back far enough in development, originate as actual pieces of living substance detached from the body of their parents. But why the unlikeness, why the differences? If cheese could grow, you could not expect pieces cut off a Cheddar to grow into Gruyère or Gorgonzola, but to remain Cheddar to the end.

This problem is one which, in general principle, we at last can understand, thanks primarily to the genius of Mendel, the Austrian abbot who first discovered the fundamental laws of heredity that bear his name; and then to the work of hundreds of biologists who during the last twenty-five years have worked along the lines made possible through the understanding given us by Mendel. The details are often complicated, and, not unnaturally, a number of minor points are still doubtful. So I shall have to be rather general and dogmatic, and must refer any one who wants to pursue the subject to books like Professor Punnett's on Mendelism, or the more recent and larger one of Dr. Crew on Animal Genetics.

The full working-out of Mendel's laws has led us to a conclusion of the greatest importance for biology. It

now seems certain that by far the most important part of the living substance which is handed on from parent to offspring consists of a whole series of tiny *units*—microscopic, or more probably ultra-microscopic—each of which has something particular to do in the business of heredity—some special work in shaping the developing egg as it grows up, and in giving the adult creature the particular characters which distinguish it from all others. These units are usually called the factors of heredity, or, more briefly, by the technical name of *genes*. We must conceive of each one of them as chemically different from all the others, and each endowed with the specifically vital power of self-reproduction. Somehow—we know nothing yet of the details—a gene can give rise to more genes like itself. Further, the genes, wherever it has been possible to test the matter, have been found to be arranged in a definite way, strung together in chains or necklaces in a regular and normally unvaried order.

The genes, like atoms or molecules, are invisible, but had to be postulated as the only possible explanation of the facts of experiment—in this case facts revealed by the experimental breeding of animals and plants. But within the last ten or twelve years it has been found possible to give these strings of genes a visible habitation within the cells of the body.

They are lodged within the objects called *chromosomes* by biologists. These chromosomes had been discovered in the middle of last century, and owe their name, which means "colour-bodies," to their convenient property of staining deeply with various sorts of dyes, and so being readily made visible in microscopical preparations. A great deal was known about their behaviour before the re-discovery of Mendel's laws in 1900; and one of the most interesting chapters of modern science has been the linking-up of these two originally quite separate lines of research—the study of cells and chromosomes under the microscope, and the study of inheritance when different strains of animals or plants were crossed—into a single whole.

The strings of genes are now known to be, or at least to be the essential parts of, the separate chromosomes which we can see through the microscope. Now one of

the important facts long ago discovered about chromosomes was that their number is normally constant for all the body-cells of any particular kind of animal or plant —fourteen for the sweet pea, eight for the fruit-fly, forty-eight for man, and so forth. Further, the individual chromosomes often differ in shape and size; and when this is so they can always be seen to occur in pairs. Finally, before the formation of the sexual reproductive cells, the number of chromosomes is reduced to half, by the simple process of one member of each pair moving into one reproductive cell, the other into another. A simple and excellent illustration is given by playing cards. If we liken each chromosome to a card, then the individual man or fly or sweet pea has two packs of these living cards in each of his cells, with the exception of the reproductive cells, in which there is only one—but, none the less, one *complete* pack.

From this, and from the fact that each chromosome contains a whole string—probably hundreds, possibly thousands—of genes, it follows that we each of us have two genes of every sort which is issued to our species from Life's stores. What experiments in breeding have shown is that a particular gene is not completely standardized—not issued in one form only; but that there may be many minor variations, each variant doing the same kind of job for the organism, but doing it in a slightly different way.

For instance, there are three variants of the gene which controls colour in rabbits. One permits colour to appear all over the body; another only allows it to appear at the tips of the ears and other extremities, as in the Himalayan breed; and the third allows no colour to appear at all, so that we have the white, pink-eyed Albino. In Indian Corn one variant of a particular gene allows sugar to be transformed into starch within the grains, while another stops the process at the sugar stage and gives us so-called sugar-corn. In man two variants of the same gene give us light and dark eyes respectively; but here other kinds of genes are also concerned, and produce different shades, such as black, brown, or hazel, green, blue, or grey, when in combination with one or other of the light-versus-dark genes.

Now what follows from all this as to the way in which genes are distributed in heredity? If we cross a pure Albino with a pure Himalayan rabbit, one dose of Albino-producing gene will be contributed in every reproductive cell from one parent, one dose of Himalayan-producer from the other. The gene for Himalayan turns out to be more powerful than the other—dominant, it is usually called,—for all the offspring will look like the Himalayan parent. But the living dose of Albino-producer is still there, as is seen if the cross-breds are mated with each other, or bred back to pure Albino stock. In the latter case, which is the simpler, the result will be that, on the average, Albinos and Himalayans will be produced in equal numbers, and that, though the Albinos will breed true, the Himalayans will again contain the gene for albinism in a latent state. Any one who will take the trouble to spend five minutes or less on the subject with a pencil and paper will easily see how this result could have been foretold. The cross-bred Himalayan contained a pair of chromosomes, one of which was carrying the gene for Himalayan, the other that for Albino. When it came to form its reproductive cells, each of these had to contain one or other, but not both, of this pair of chromosomes; whereas all those of the pure Albino contained chromosomes with a gene for Albino. Put it in briefest form—if gene for albinism be called *a* and gene for Himalayan *A*, then the cross-bred Himalayans were of constitution *Aa*, and of their reproductive cells half carried *A*, half *a*—whence immediately follows the 50 : 50 result of the cross back to the pure Albino. Even if two cross-bred Himalayans had been mated with each other, pure-breeding Albinos would have been recovered (though only to the tune of 25%) in the next generation; and this recovery of the pure original types used in making the cross is of the greatest importance.[1]

[1] We can summarize this in diagram form as follows:

Himalayan parent	AA	×	*aa* Albino parent:
reproductive cells	A		*a*.
Offspring		A*a* (appears of Himalayan type)	
reproductive cells		50% A	
		50% *a*.	

When two of the offspring are bred together, the reproductive

When a gene resembles that for albinism in not showing its characteristic effects when in presence of a dominant partner, it is called *recessive* : and the above result shows that two individuals—whether human beings, or other animals, or plants—may be carrying such recessive characters without their showing at all, but that yet they will reappear in full force in later generations when the right mating occurs.

So much for the simplest case, when only one kind of gene is involved. But what will happen if two genes are involved, situated in different chromosomes? Let us take guinea-pigs instead of rabbits for our example. In this species, two varieties of one gene produce albinism and colour, as in rabbits; while two varieties of another gene affect the hair, causing it to lie smooth in one case, to be rough in the other. What will happen if an animal of a pure rough-haired coloured strain is crossed with one of a smooth-haired Albino strain? In the first generation all will be coloured and rough-haired, as these are dominant characters; but if these cross-breds are mated with each other, all possible combinations of the two characters will be found—not only the two which were found in the original strain, but also rough-haired white and smooth-haired coloured beasts, some of which will breed true. Supposing that *only* rough coloured and

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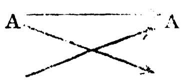
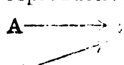
cells are as follows, and the different types of union possible are indicated by arrows :



Result in second generation :

25% AA	50% A*a*	25% *aa*
pure Himalayan.	Hybrid, but appear of Himalayan type.	pure Albino.

If the hybrid had been crossed back to the Albino, the possible types of union among the reproductive cells would be :



Result :	50% A*a*	50% *aa*
	hybrid of Himalayan type.	Albino.

smooth white strains had been known before, then two quite new strains would have been brought into existence by combining the old factors into new arrangements through crossing.

If the cross, instead of being between a rough coloured and a smooth white strain, had been between a rough white and a smooth coloured, the results would have been exactly the same.[1] So here we are introduced to two new principles. First, that by crossing two strains differing in more than one kind of gene, all possible quite new combinations will be produced in later generations; and secondly, that genes are independent units, and that

[1] Let C be the colour-producing gene, *c* that for albinism, R that for rough hair, and *r* that for smooth hair.

Then in the first case the parents are CCRR × *ccrr* :
their reproductive cells CR *cr*.
The offspring will be of constitution C*c*R*r* :
their reproductive cells CR, C*r*, *c*R, and *cr* in equal proportions.

When two of these are mated together, each of these reproductive cells has an equal chance of union with any of the four types from the other sex. This is graphically represented in the square below, constructed on the principle used in match tournaments.

	CR	C*r*	*c*R	*cr* ova
CR				
C*r*				
*c*R				
cr				

sperms

If any one will take the trouble to fill in the squares, he will find that of the 16, 9 will contain C and R and therefore appear coloured and rough, 3 C and *rr* (coloured and smooth), 3 *cc* and R (Albino and rough), 1 *cc* and *rr* (Albino and smooth):

In the second case the parents are *cc* RR × CC *rr* :
their reproductive cells are *c*R C*r* :
and their offspring will be C*c* R*r*—*i.e.* the same constitution as before.

the results of a cross do not depend on the way the genes were combined in the parents, but merely upon the number and kind of genes, however arranged. (This second principle does not hold good exactly for different genes which are close together in the same chromosome, but this will concern only a small fraction of the total number.) We have seen that when two strains are crossed which differ in respect of two pairs of genes, we get four separate combinations in later generations. If they had differed in regard to three, there would have been eight combinations; if in four, sixteen combinations; and so on, until a cross between two strains differing in respect of only ten genes will give us over a thousand new combinations; and one differing in regard to twenty, over a million!

Now the reason why all the children of one marriage are not exactly like their parents and each other begins to be clear. For no two of the sperm cells of any father will be exactly alike in the pack of genes which they receive, nor any two of the egg-cells of any mother; and, further, every now and then an exceptional paternal combination will meet an exceptional maternal set, and an exceptional offspring, unlike the ordinary run of the family, will be the result of their union.

Let us return to our metaphor of cards, but apply it to the genes instead of to the whole chromosomes. The genes that each of us contains are the cards with which we must play the game of life. They have been dealt to us once and for all at the moment of fertilization, and we cannot draw new ones from the pool. But the gene-cards are a little different from ordinary cards, in that one kind of gene may turn up in slightly different values; it is as if each card could be a little above or below par—there could be an above-par seven of hearts, for instance, and a below-par one, as well as one of standard value. Then, when the reproductive cells are formed, a single pack is chosen for each one out of the two packs present in the individual parent; and this single pack may obviously be chosen in a vast number of different ways, sometimes consisting mostly of above-par genes, sometimes the reverse, though usually with above-par and below-par genes roughly cancelling out

to give something near the average. And, finally, it is again a matter of pure chance what sperm out of the many millions that swim round the egg shall be successful in fertilization, so that, for every personality which comes into being, literally millions of possible ones are never formed, and remain for ever unrealized—a strange and haunting thought.

The fable that men are born equal is thus disproved by the facts of biology, although, as a matter of fact, its lack of truth is fairly evident from common observation. The workings of heredity deal different cards to each of us. But, though our destinies are largely at the mercy of these cards, they are by no means wholly so controlled. To varying extent they are determined by the conditions in which the new life unfolds; but that must be dealt with in another chapter.

The great advance that recent studies in heredity have made possible is in giving us some understanding of the material basis of inheritance. We each of us, and each of the higher animals and higher plants as well, are what we are because of a material something which has been bequeathed to us by our parents. This *something* consists of a definite set of chemical units or genes which co-operate to build up the individual. These genes have each their own station and their own special work; so that some day it may be possible to give a formula for the heredity or gene-composition of an individual, as we now can write formulæ for even complex chemical substances. Already, for instance, the difference between a silver-fawn waltzing mouse and an albino variety derived from a wild stock of mice can be expressed by saying that one has the genes CC. *bb. gg. dd. ww.*, while the other has *cc.* BB. GG. DD. WW., and these formulæ already enable us to predict a great deal about the results of crossing them; for instance, that the first generation would all be grey like the wild mouse, and non-waltzing, and that in the next generation we should get not only grey, albino, and silver fawn, but also black, blue, chocolate, cinnamon, and other-coloured mice, and that some of each colour would be "waltzers," others not.

To have found that the hereditary constitution is

made up of units, and that these may be re-arranged in all sorts of combinations, is a very great step in advance, comparable in its way to the proof of the atomic theory, which introduced the idea of separable units into chemistry. Just as the chemist, working on the basis of the atomic theory, can pull substances to pieces and build their atoms up into new forms, so the biologist, working on the Mendelian theory, will be able to build up new forms of life by making new combinations of genes—a process already followed, though not consciously, by Luther Burbank, and consciously by Professor Biffen at Cambridge in making new wheats.

With special questions of human heredity I shall deal in another talk. What it is that causes one kind of gene to occur in two or more variations is also a problem I must leave till later—here we must simply accept the fact that this does happen. Let us conclude by reminding ourselves that some genes control colour, others height or weight, others fertility or length of life, others vigour and the reverse, others shape or proportions. Possibly all, certainly the vast majority, of hereditary characters are gene-controlled. For mental characters, especially the more complex and subtle ones, the proof is more difficult, but there is every evidence that they are inheritable, and no evidence that their inheritance is due to a different mechanism from that for bodily characters. That which is inherited in our personality and bodily peculiarities depends somehow upon the interaction of this assorted battery of genes with which we are equipped at fertilization.

The flow of life is continuous; but each little section of each of its streamlets—each individual man, or animal, or plant—is different in quality, it may be much or it may be little, from every other; and this difference is due in the main to the shuffling and re-dealing of the genes, the ultimate living units of heredity of which the Abbot Mendel, working with his peas in the quiet monastery garden at Brunn, was the first to catch a glimpse with his penetrating mental vision.

Chapter III

Development

THE contrast between the grown-up individual, animal or man, with which we are familiar, and that same individual at the first instant of its being, is one of the constant miracles of existence, which, like life or like existence itself, is only not remarked because it is always with us.

On the one hand is a sentient creature furnished with means of locomotion, digestion, protection against invaders, with a marvellous mechanical scaffolding for support, a transport system in which traffic is never held up, elaborate instruments for registering change in the world around, and, in the shape of the nervous system, machinery for controlling and co-ordinating the separate parts into a whole before which the telephone installation of the largest city in the world or the organization of a modern army pale not merely into inefficiency, but insignificance.

On the other is the fertilized egg, a single cell, with no trace of any of these organs. The fertilized egg is almost always small, though larger than most cells. Only exceptionally do we find really large eggs, such as those of birds, dogfish, or cuttlefish, and this large size is due to the accumulation of reserve stores of dead food-material in the shape of yolk. That of man is well below the average size, being only about 1/120th of an inch across.

The first stage in development is called segmentation. The single egg-cell segments or divides itself into two, then four, and so on until there are hundreds of tiny cells in place of one large one. The general significance of this is simple. The original egg is comparatively large, since it has to contain food-stores to tide the embryo

over until it can fend for itself; and it segments because it must have bricks of convenient size for its future building operations.

Next comes the laying-down of a first crude ground-plan, in the form of definite layers or membranes of cells. In all higher animals three of these layers are produced. The outermost is destined to give rise to the outer skin, the nervous system, and the sense-organs; the innermost to the digestive tube and its glands, and, in land vertebrates, to the lungs; and the intermediate layer to all the remainder—blood, internal skeleton, kidneys, muscles, reproductive organs, and the rest.

The next or third main stage consists in blocking out the plan of the main systems of these organs. It may be seen by any one who takes the trouble to watch a batch of developing frog-spawn in the spring. The embryo, up till now quite round, begins to elongate. A shallow groove appears along its back, and the thickened lips of this groove grow up and arch over to meet and so turn the groove into a hollow tube. This tube is the future nervous system. The cavity surrounded by the innermost layer elongates and moulds itself to form gullet, stomach, and intestine, and buds out branches which will become liver and sweetbread (pancreas). The middle layer at the sides chops itself up into blocks which are destined to grow into muscles; and below, some of its cells join up to form a hollow bag, the lining of the future heart; little protuberances appear on the sides of the body, to become the rudiments of limbs; and so on with the rest of the organs.

But though by the end of this stage all the chief organs of the body are visible, they are not yet at work—and indeed not capable of working. The cell-bricks of which they are built are still almost all alike. The next step is for these cells to change so as to be capable of working for the good of the whole. Some cells elongate, develop contractile fibrils, and become muscle-cells: others turn into the little chemical factories we call gland-cells: others, becoming flat and horny, acquire the protective characters of outer skin: still others sprout forth long threads which will conduct impulses like living telephone wires, and thus become nerve-cells;

and so on. This stage we may call the stage of cell-differentiation.

Up till this point, in a creature like the frog, whose eggs are laid free in the water, no food has been taken in, but the embryo has lived entirely on stored-up yolk. Now, however, it hatches out as a tadpole, and begins to feed and consequently to grow. But growth is not the only chief characteristic of this next period. The developing animal now becomes much more unified than before. This unification comes in two ways. In the first place, the blood-system has begun its work, and accordingly every part of the body is bathed with one and the same circulating fluid, the blood, which we can think of as the animal's internal environment. Into the blood-stream chemical messengers or hormones can be poured out by special glands like the thyroid and the pituitary; and these may simultaneously affect the growth of several parts of the body. What is even more important, every part of the body is now bound together by means of the nervous system, so that messages can be flashed from one part to another, and the whole put under the single control of the brain. This period we can therefore call the period of unification and growth.

Growth gradually slackens, as we all know, and in man and higher animals comes to a stop, so that we get a stable period of adult life. But it is not generally realized that primitively there is no such fixed adult size, and that animals like crabs or fishes go on growing so long as they live.

Finally, old age supervenes, though it must be rare under natural conditions; and this leads on to an inevitable or natural death, as opposed to accidental death that may come from enemies, or accident, or disease. In some flies the whole life-cycle till death takes only a week: in the giant tortoise, hundreds of years; and there are all intermediate lengths.

So much for the different stages of development. Now for some account of the different workings and reactions of the animal at each stage.

The first period, of segmentation, is usually very plastic. If, in a newt's egg, the first two cells to be formed are artificially separated from each other, each, instead of

continuing development as a half, may turn into a half-sized but healthy whole, so that we get two newts instead of one. There is no reasonable doubt that so-called "identical" twins in man are produced in the same general way, through an accidental splitting of a single egg during the segmentation stage. Conversely, two fertilized eggs have been made to join up and give a single giant embryo.

If the egg be damaged during this period by exposure to unfavourable conditions, chemical or mechanical, all sorts of monstrosities result. One of the commonest is for the whole front region to be under-developed, so that, for instance, there may be no nose and only a single central eye. Another is a partial doubling, giving rise to two-headed or two-bodied monsters, like incomplete Siamese twins.

Once the ground-plan stages are reached, however, everything is changed. All the parts now work out their own destiny independently of each other, as if by a sort of vital clockwork. An embryo cut in half at this stage will go on developing, each half for itself: a limb-bud cut out and grafted, say on to the back, will none the less turn into a limb in its new position. Some extremely complicated chemical machinery must be set in train at the close of the first period, and this, if the conditions are possible for life at all, works itself out to the end of the stage of cell-differentiation, each part independently of the rest.

But when the animal begins to work on its own account, another great change is seen. For one thing, the secretions of the ductless glands, which now begin to exert their wonderful effects, may be changed in amount by outward influences. For instance, in certain conditions of temperature the thyroid gland of the tadpole can be made unusually active; and as a result the tadpole turns into a frog at a much earlier and smaller stage than usual. Or, again, absence of the thyroid in the human embryo leads to the terrible condition, stunted both in body and in mind, known as cretinism. This is a very instructive example, as it shows the complicated interrelations of development. Cretins are imbecile, and it would be natural to suppose

that this was due to some inherent defect of brain. But no—cretins may be wholly cured by thyroid treatment, so that we see that the brain will only develop, however good its inherent possibilities, if thyroid secretion is present.

Not only this, but different amounts and quality of food have their effect; and the actual working of the organs may have a powerful influence upon their later development. Every one knows that long-continued heavy exercise will make the muscles actually increase in size; but other even more striking facts are not so familiar—such as that feeding a sea-gull on corn will make it develop a horny gizzard, not unlike that of a fowl, or that a piece of living bone grafted in to take the place of a damaged bone, for instance in the finger, will be gradually moulded by the stresses and strains of the muscles to become a very passable imitation of the bone for which it is doing duty; or, again, if the leg of a new-born animal, like a puppy or a kitten, be tied up for some weeks so that it cannot be used, not only the muscles but the bone itself will refuse to grow to nearly the same extent as in the legs which are used. So the old proverb, "God helps them who help themselves," is true even of the organs within our bodies.

Finally, there are all the influences of the outer world to reckon with. Not enough iodine in our food and salt, and we (and all vertebrates) develop the disease of the thyroid known as goitre; and if a woman has this badly, her children may be cretins; give children plenty of ultra-violet light, and they tan, and grow vigorously. In lower animals and plants the effects may be more striking still. Expose a sea-urchin egg to too much lithium, and the embryo will grow up more or less inside-out! Every one knows the effect of persistent wind in one direction on the shapes of trees; and all sorts of monstrosities can be produced in young fish or tadpoles by playing various simple tricks on the eggs. Magnesium chloride, for instance, will cause them to grow up with only one eye, as described above.

Development is thus an amazingly complicated process, and can be interfered with, often with disastrous results, by quite small changes in the outer conditions. Why

then does the development of man not go astray more often? why are there not a large number of monstrosities or abnormalities born instead of the comparatively few that do occur?

The answer is that in man, in common with all higher mammals, the whole of early development is marvellously sheltered from the outer world. The embryo, nourished within the mother's body, grows up in an environment which is as constant as it well could be. The temperature is uniform, there is no disturbing change of light, its food is pre-digested, and the chemical composition of its surroundings is constant because those surroundings are to all intents and purposes wholly represented by the mother's blood.

But once the child is born, the rest of its development is subjected not only to the inner push, so to speak, of hereditary forces, but to all the play of a very variable environment, so that the grown man is always a double product, partly of what he was given at the start in the way of hereditary outfit, partly of the moulding he has received at the hands of the outer world.

That is a line of thought to be pursued further when we come to consider more in detail the shares of nature and nurture in moulding human life.

I have not yet mentioned what is known as recapitulation—that wonderful tendency of developing animals to pass through stages which seem to represent past ancestral stages of the race, or, as it has been rather frivolously put, to climb up their own family tree.

Each one of us started as a single cell—like the primitive single-celled animals known as simple Protozoa. We then became a colony of cells—like colonial Protozoa; then a mere double-walled bag, the only trace of an organ being the internal cavity which will be the digestive tube—in which stage we were not unlike a polyp. Some time later we reached a condition in which our architecture was essentially that of a fish; then one more or less reptilian; and then mammalian. But we still were tailed, and only after passing through a monkey-like phase and shedding a crop of hair were we born—and even then still had to develop our highest and most typically human brain-centres.

So before going on in my next talk to the subject of Evolution—the slow evolution of species and groups—I would remind you that, in development, every one of us and every animal and plant goes through its own individual and rapid evolution, leaping from stage to stage, from one type of structure to another, acquiring complexity out of original simplicity, creating something (and a very wonderful something), if not out of nothing, at least out of very little.

If there be any who are sceptical about Evolution, let them remember their own: it is worth studying!

Chapter IV

Evolution: I. The Problem

THE business of the man of science may be summed up in two words—firstly, " What ? "; and secondly, " How ? ".

So those men of science who have devoted themselves to the study of living things have had to try to find out what manner of living things exist, and then, if possible, something of how they have come into existence. It is this latter problem which I propose to deal with here, and I shall simply try to present some of the evidence, in the shape of known facts, on which the scientist has to make up his mind.

In the first place, then, there are an enormous number of different kinds of animals and plants—many more than most of us would imagine. There are over half a million different species of animals, let alone plants, already described, and new ones coming in every week to the museums of the world. In this country alone there are several thousand separate kinds of the single group of beetles, each of them distinct and true-breeding. However, this great army can be classified into a comparatively small number of main types or groups. To take but two of the most successful groups, there are the vertebrates, or backboned animals, to which we ourselves belong, and the arthropods, or forms with jointed legs, which include the insects, the crustaceans, and the spiders. Now if we compare any two vertebrates, such as, for instance, a frog and a man, we find that in spite of plenty of difference in detail there is a fundamental similarity in ground-plan. Both have teeth, a single pair of jaws with up-and-down movement, two pairs of limbs, red blood, heart on the ventral

side, nerve-cord along the back, and an internal skeleton with a backbone.

A lobster, on the other hand, has several pairs of limbs, several pairs of jaws, with side-to-side movement, heart along the back, nerve-cord where the vertebrate has its heart, no backbone, but a skeleton on the outside, compound instead of single eyes, and almost colourless blood. What is more, it would share most of these peculiarities with a cockroach or a spider, or indeed with any and every arthropod; and similarly the rest of the vertebrates would show all or most of the characters we have enumerated for the frog and ourselves.

Now, in spite of this difference in construction between arthropod and vertebrate, it cannot be asserted that one type of plan is much better or much worse than the other. A lobster is about as high an animal as a newt, and performs a similar variety of functions.

Why then is there this difference of ground-plan among animal groups?

Furthermore, the ground-plan persists in animals adapted to all kinds of life. For instance, the ground-plan of the fore-limb of mammals remains recognizably the same whether the limb be used for running, as in a horse, for swimming, as in a whale, for flying, as in a bat, or for grasping, as in man; and the so-called appendages of a crustacean retain the same essential plan whether employed as feelers, as jaws, as walking legs, or as swimmerets.

How is it that the plan persists through such change of function in the members of one group, while in another group there will be quite a different plan?

Another important set of facts is afforded by the study of development. As was noticed over a century ago, animals tend to become more and more like each other the further back in their development we study them. No one would be likely to confuse a pig, a cow, a bat, and a man—when grown up. But only an expert could tell them apart as early embryos. Still more remarkable, the early stages of many animals are often provided with organs which are not present in the grown-up individual, but do occur in other creatures

belonging to the same great group. For instance, man and the frog again resemble each other in this—that at one stage of their development they both possess a tail like the majority of vertebrates. They also possess what are known as gill-slits—clefts on either side of the throat. In the tadpole, and in all the kinds of fish, water is forced through these and so over its gills, which are, of course, breathing organs for taking up oxygen from the water. But in man, though gills are never developed (since the human embryo gets its oxygen from its mother's blood), the gill-slits are there just the same.

At an earlier stage still, both man and frog embryos show no sign of a jointed backbone, but instead of it a single rod called the notochord, which is found in the adult of low vertebrates like the lamprey.

Similarly, the embryo of the whalebone whale has definite hind-limbs and definite teeth, although the adult has neither; and the human embryo not very long before birth is covered all over with a coat of close hair.

We may make the matter of the gill-slits more emphatic by putting it in this way:—every human being passes through one stage of its development when the general plan of its construction is like that of a fish instead of like that of a land animal.

Somewhat similar facts are provided by what are known as vestigial organs—organs which have no use in the animals where they are found, but are of the same nature as organs which are of obvious use in other creatures. To go no further than ourselves, although we lose our coat of close hair before birth, we are still covered with rudimentary hairs, which can be of no possible service in keeping us warm; and no one has found a use for the human appendix, though it is large and important in herbivorous animals like the rabbit. Again, just a trace of hind-limb skeleton is still to be found in the full-grown whale and some snakes, although it cannot be of the slightest service; and the tiny splint-bones on either side of a horse's limb-skeleton are vestiges of toes.

Why are such vestiges in existence?

Next, there are many facts of the distribution of animals and plants over the earth's surface. Everybody

knows that different animals come from different regions; but it is not always grasped that different regions often differ in respect of whole groups of animals. For instance, South America is the only home of the Armadillos, the Sloths, the Vampire bats, the true Ant-eaters, and the Llamas; but totally lacks antelopes, sheep, and oxen as indigenous products. Again, Australia when discovered had on it none of the higher mammals except those that could fly (together with the dingo dog and rats and mice, probably introduced by the natives); all its other mammals belonged to that lower grade known as marsupials, which carry their young in a pouch, like the Kangaroo, Wallaby, Wombat, and so on.

It used to be supposed that each species lived in the region to which it was best suited. But this is not the case. Every Australian farmer knows to his cost that the rabbit is better suited to Australia than are its own animals; and in the same way the introduced American water-weed was so admirably suited for life in our water-ways that for some years it was a real hindrance to inland navigation.

When we come to details, the matter becomes even more interesting. One of the facts that most impressed Darwin on his voyage in the *Beagle* was the extraordinary distribution of the animals and birds on the different islands of the Galapagos archipelago. This is a scattered group of islands, about 600 miles from the west coast of South America. Mocking-birds occur on the islands; but almost every separate island has its own distinct species! and the same is true of the finches and of other kinds of birds and animals. How is it that each little island should be provided with its own special finch and mocking-bird, while similar birds on continents range over large areas?

Finally, we come to the most interesting evidence of all—the evidence provided by fossils. Fossils, as everybody knows, are the remains of animals or plants which have been preserved after death in what are called sedimentary rocks, *i.e.* rocks which have been laid down layer by layer under water, like chalk or sandstone.

The first step in their study was taken when it was realized that they actually were the remains of dead organisms, and not merely accidental concretions of the rock. The second, when it was found that some of them were the remains of organisms no longer to be found living. Then came the great discovery of the English geologist William Smith, that the different kinds of sedimentary rocks of which the earth's crust is made are not arranged anyhow, but have a regular sequence. For instance, the Gault clay and the greensand are always found lying under beds of chalk, while the London clay lies above the chalk. This can only mean that in the past history of the earth the chalk was deposited later than the greensand, and the London clay later again than the chalk. It thus becomes possible to construct a time-scale for all the different sedimentary rocks known, arranging them in the order of their coming into existence. These relations of one layer or formation of rock to another are naturally best seen where the different layers have not been much disturbed since they were first laid down, as is the case over this country and much of North-Central Europe. Where, however, great earth-movements have taken place, which bring about folding and crumpling and the raising of huge mountain ranges, as, for instance, in the Alps, the layers may get forced out of place, even turned upside down, so that their relations to each other are much harder to disentangle.

Once this time-sequence was established, a momentous advance could be made with regard to the fossils. When these were examined, it was found, not only that certain of the fossils of one particular layer were the same wherever that layer was found, but that the fossils changed from layer to layer. Certain special kinds of fossils, such as, for instance, various kinds of common sea-shells, were found to be absolutely constant in one layer, certain other kinds of the same general sort of shell in another layer. Such fossils are called index-fossils, since they are so typical and constant. When we find a layer in some other part of the world, and are at a loss to tell where it belongs in our series because of crumpling or folding, or for some other reason, we

can date it instead by means of its index-fossils, if we can find any. In just the same way we could date a deposit of rubbish as dating from Roman times if we found in it abundance of coins and pottery of a type known to be Roman—even though this layer might be isolated, and not covered, as is sometimes the case, with other layers containing remains of later historical periods.

People sometimes say that this is arguing in a circle—the fossils are first dated by reference to the layers of rock, and then the layers of rock by reference to the fossils. This is not really so, however. The fossils are first dated by reference to their positions in undisturbed layers of rock, in which there is no possibility of being mistaken as to which was laid down earlier and which later. Only when it has been shown, in cases where no doubt exists as to the dating of the layer, that the fossil is never found in other kinds of layers is it used as an indication of date in cases where the position of the layers does not help us.

Now by this means it is, of course, possible to arrange the known fossils of any particular group in order according to time. And the remarkable fact then emerges that, although in some cases the fossils show no change, in the great majority gradual and orderly changes can be traced. The most interesting of these series of changes is perhaps that which concerns the different main groups of backboned animals, which are five—fish, amphibians (frogs, toads, newts, etc.), reptiles, birds, and mammals. All five classes exist to-day, and in all the most recently laid down rocks. There comes a time, however—about the middle of the so-called secondary epoch, the middle of the three great periods into which the fossil-bearing rocks are divided—before which neither birds nor mammals are any longer to be discovered. The reptiles can be traced somewhat further back into the past, but they too then disappear, and the only land-group remaining is that of the amphibians, several of which were then much bigger than any to-day, resembling great salamanders of over six feet in length. The earliest of these lived in what is called Carboniferous period, when our coal-measures were being

laid down. But before this, they too are wanting, and the only vertebrates in existence lived in the water, in the shape of numerous fish. Thus the book of the rocks, which cannot lie, shows us that the different groups of vertebrates appear at different times, the lowest first, the most highly developed at the last.

When we go more into detail, the facts become even more wonderful. For instance, the earliest bird known, from the middle of the secondary period, although obviously a bird, with wings and feathers, differs in many ways from modern birds. It had large teeth; its tail was not a fan, but a double row of feathers on either side of a long jointed axis of bone; and, most remarkable of all, it had on its wing, besides feathers, three separately movable fingers ending in claws, by whose aid it doubtless scrambled about through the branches. In all these ways Archaeopteryx, as it is called, was less fully adapted to aerial life than are modern birds, and is a real link between the two apparently separate groups of Birds and Reptiles.

When we come to the familiar four-footed beasts or mammals, wonderfully graded series can often be traced. The horses, for instance, were not always like the horses of to-day. The modern forms all have only one toe to each foot, with tiny rudimentary bones on either side, the so-called splint-bones, as sole remains of the other toes. At an earlier stage, however, the only horses to be found had three toes, all with hoofs, but the middle one much the biggest. Still earlier there were horses with three practically equal toes; and the earliest known had four toes on the front feet. In the same way, fossil elephants form a series in which the earliest forms were small, with simple teeth and short trunks; and as we advance in time, we can find various stages leading to larger bulk, to longer trunks, and to the greater size and complexity of grinding teeth which are to be seen in the living forms.

Finally, we can often see a relation between the fossils of a particular region and the type of animals that live there to-day. South America, as I have already mentioned, is the only known home of the armadillos (with the exception of one or two kinds

which have wandered some way up into the United States); and in South American rocks (and, up to the present at least, nowhere else) fossil armadillos have been discovered which, though obviously armadillos, are different from any of the living forms.

Let us sum up. We find that each great group of animals is characterized by one general ground-plan, and that the ground-plan remains the same in spite of enormous differences in detail and in the uses to which each particular organ may be put. We find that animals resemble each other more at early stages of their development than at late stages, and that they often show characters in early development which have no meaning in relation to their final mode of life, but resemble useful characters seen in other forms with other modes of life. We see animals which even when fully grown show vestiges of organs which serve, in them, no useful purpose, but are large and useful enough in other creatures. We see animals distributed in a peculiar way over the face of the globe; and finally we see that the animals that exist now have not always existed, but that whole groups appear during the course of the earth's history, and that within these groups there are to be found series of fossils gradually leading up, through geological time, to the types we know to-day. And all these statements are true of plants as well, though often not so clearly shown.

There are the facts; and they constitute our problem. What do they mean? I may as well conclude by anticipating a little of my next chapter. They can all be accounted for if we suppose that the animals and plants that we know are not fixed, but that they have been gradually evolved or developed from other forms, and that, in fact, the whole organic kingdom has suffered a gradual evolution, moulded by its inner urge and by the strong guidance and pressure of outer circumstance. This is the theory of evolution, or, as it is sometimes called, of descent with modification, which is now held, in some form or another, by every biologist.

Because the facts *can* be so explained is not necessarily to say that the theory is true. But, on the other hand, no one else has ever advanced any other theory which

will account for the facts, and the circumstantial evidence for evolution is so strong that it is overpowering. If a jury had circumstantial evidence one-tenth—one-hundredth—as strong and as extensive before them in a case, they would unhesitatingly convict on it. The best way to sum up the view of those who have studied the facts—the professional biologists—is to say that they are driven to accept the evolutionary conclusion; that when they act on it, it works; and that they have not found or been offered any other conclusion which is even remotely so effective or so satisfactory.

In my next talk I shall give some account of the theories which have been put forward to account for evolution taking place—the method by which it may be supposed to work out its progressive changes.

Chapter V

Evolution: II. The Solution

IN my last talk I brought together some of the facts which pose us with the question of how the different known kinds of animals and plants have come into being. And I hope I was fairly successful in showing that, as is always in the long run the case in science, the facts dictate the answer; and that answer is Evolution. If all mammals are descended from one original primitive mammal, then it is quite easy to see why the original ground-plan of the fore-limb, say, should have been retained, whether the details became modified for flying, swimming, running, or any other function. If birds rarely fly across the sea between the various Galapagos islands, there will be opportunity for the birds on each island to develop along a line of their own and form a separate species; and so on.

But it is one thing to be forced to believe that evolution must have occurred; and quite another thing to understand *how* it could have occurred, and by what possible machinery. It was the surpassing merit of Darwin that he not only accumulated and marshalled an overwhelming mass of evidence which spoke for the fact of evolution, but was the first to show that a possible method existed to account for evolution taking place.

One of the first things which strikes every student of life is the amazing way in which organisms and their organs are fitted to their particular mode of life, often like hand to glove. These fitnesses we generally speak of as adaptations, and it was obviously one of the main tasks of a theory of the method of evolution to account for them. Broad adaptations are, of course, everywhere. Men are adapted to live in air, fish to live in

water. The teeth of herbivorous animals like cow or horse are beautiful little millstones, while those of carnivores like wolf or lion are built for cutting and tearing. Sometimes, however, the adaptation is amazingly special and detailed. Many animals are protectively coloured—that is to say, escape detection by enemies through resembling their surroundings. Sometimes this resemblance is almost incredible, as in certain tropical butterflies which when at rest resemble dead leaves, not merely in shape and colour, but also in being marked with imitation midrib and veins, and in some species even with round blotches simulating spots of decay, or transparent patches pretending to be holes! And every botanist will recall plenty of striking adaptations of flowers to cross-fertilization by particular insects, such as the beautiful lever construction of the stamens of the sage-plant; when a bee enters the sage flower, it must push against the short arm of the lever, upon which down comes the long arm and dusts pollen on the bee just where she will rub it off against the pistil of the next flower, and so ensure fertilization.

Paley, in his famous treatise, had used such cases of adaptation as proofs of the existence of purposive design on the part of a creator. Darwin showed how adaptations could be accounted for by natural causes, and that therefore the design or purpose was only apparent.

His line of reasoning was based on three sets of facts. First, there exists for every species a struggle for existence, which comes about automatically owing to the number of young being always greater than can survive. Even with the slowest-breeding creatures, like whales and elephants, every pair produces more than two young, so that a simple calculation will show that if they all survived and repeated the process, it would be merely a question of time for them to choke up the world. In the case of rapidly-breeding creatures, like some microscopic forms of life, the rate of increase is even more startling. Many bacteria reproduce almost every half-hour. If it were possible (which it luckily is not!) for every one of the offspring to survive and reproduce in its turn, it would be only a matter of weeks before we were confronted with a mass of bacteria

as big as the earth, and a few years before it surpassed the solar system in size.

As a matter of fact, of course, the numbers of any species remain more or less constant. I introduce these examples merely to show what a pressure there must be, what competition for the means of existence between members of a species owing to this struggle and the consequent death of the majority before reaching maturity.

The next point is that variations are constantly occurring, and that many variations are inheritable. Apart from the variations due to new combinations of old hereditary factors or genes, we are confronted with what are known as mutations, or alterations of a gene from one form to another. A large number of these have been carefully studied in the little fruit-fly called Drosophila. Some of them have marked effects, such as reducing the size of the wings to almost nothing; others have very small effects, such as causing a slight change in eye-colour. But all are inherited.

Granted that there is a struggle for existence, and that there arise new variations which may be inherited, then the conclusion which Darwin called Natural Selection inevitably follows—that more of those animals which happen to possess favourable variations will survive, more of those with unfavourable variations will die out, so that gradually the animals with favourable variations will altogether supplant the rest.

Of the causes of mutations or inheritable variations we as yet know practically nothing. But we know that they occur, and it then follows mathematically that, if they confer any benefit on their possessors in the struggle for existence, they will come to survive in greater and greater proportions. It will take a very long time, perhaps hundreds of generations, before a mutation which confers only a small advantage will totally supplant an old gene, but a hundred generations is not a long period compared with the millions of years in which geological time is reckoned.

On this theory, the way in which animals change is quite different from what is often supposed. They do not change because they want or try to change—an animal cannot alter its instincts or the shape of its

body any more than we can add a cubit to our stature by taking thought. Changes take their rise in alterations in the genes, the chemical basis of heredity; and then some of these changes are automatically weeded out, while others are encouraged and the old genes are supplanted.

Natural Selection is essentially a sifting process: the mixture to be sifted is represented by the different variations: the mesh of the sieve is the particular environment in which the creature lives, and the force of the man throwing the earth against the sieve is the pressure of the struggle for existence.

Other theories have also been put forward to account for evolution. The only one which we need consider here is what is usually called the Inheritance of Acquired Characters, first put forward by the French naturalist Lamarck half a century before Darwin's *Origin of Species*. This theory assumes that the effects of use and disuse may be inherited, and also the effects of the environment. For instance, the Lamarckian view about the vestiges of hind-limbs in the whale would be that because the hind-limbs were not used they failed to grow to their full size, and that this was inherited, in the sense that the next generation would have hind-limbs whose capacity for growth would be not quite so great; and that the process was accentuated from generation to generation. Again, the effect of tropical sun in tanning the skin of white men is a commonplace; but the Lamarckian view assumes that this tanning should be transmitted in some degree to the children, even if they were only exposed to the sun of temperate regions, so that generations of tropical exposure should produce a dark brown or black-skinned race.

The theory of Natural Selection, on the other hand, would say that the effects of tanning were not in themselves inherited. But, since too strong light is injurious, and pigment stops the light from penetrating, it will be of advantage in tropical climates; and so, if a white race were to invade the tropics, any individuals who happened to possess variations in the direction of darker skin would survive in greater proportion than their lighter brethren. Something very like this has repeatedly occurred, it would seem, in human history.

Fair-haired northern invaders have poured down from the north into warm-temperate or tropical regions like Greece and India; but to-day few or no blonds are to be found in those regions. The matter is here simplified in a sense through the invaders having intermarried with the natives, who were apparently already dark. In later generations all kinds of combinations of the characters of the two races would be formed according to Mendel's laws, and there was encouragement, by Natural Selection, of those combinations without fair skin.

In the same way, the theory of Natural Selection would account for the gradual disappearance of the whale's hind-limbs, by pointing out that, since they got in the way of rapid swimming, any variation in the direction of smaller limbs would be encouraged.

This question of the inheritance of acquired characters is of enormous practical importance to man, and I shall discuss it at greater length in my next talk. Here I shall only say that so far no completely satisfactory evidence has ever been brought forward to show that it can take place, and a good deal to show that in many cases it does not take place. It is quite possible that with a few kinds of characters it may be at work, but practically certain that it has played no large part in evolution. With regard to Natural Selection, on the other hand, we know that mutations which can be inherited *are* taking place; and, this once granted, the rest follows as a necessary consequence of the struggle for existence.

No biologist pretends that we have any but the most rudimentary knowledge of the origin of inheritable variations—that is, for the present one of the outstanding problems of science; but most are agreed that Natural Selection, acting on the raw material presented by variation, is the most potent, if possibly not the only factor working to bring about evolutionary change.

What a different view this gives us from that of Paley! There is now no trace of conscious design. Variation is at random, in all directions—good, bad, or indifferent. The blind pressure of the struggle for existence sets in motion the equally blind forces of Natural Selection, with the result that harmful variations are bred out of the stock, useful variations bred in. The whole process is as superbly inevitable as the motions

of the planets. Conscious purpose appears as a faint glimmering in the higher animals, but only plays an important rôle in evolution when we come to man.

This is sometimes called a gloomy view, sometimes a materialistic one. Even if it were gloomy and materialistic, we should have to accept it if it were true; but as a matter of fact it is neither. It is not materialistic, because the most notable feature in the later stages of evolution has been the development of mind to ever greater heights, until it has become the most important single factor in the process. The purely bodily machinery was perfected earlier: later development has consisted in the improvement of the mind to guide and control this machinery.

It is not gloomy, because it has led to progress. There can be no doubt that evolution has brought into being a gradually improving series of creatures, increasing in strength, in efficiency of parts, in harmony of running, in control over natural forces, in intensity of emotion, in intelligence, in mental power, and finally, with man, in spiritual and intellectual capacity.

We do not know, but it is in every way the simplest supposition to make, that thousands of millions of years ago, when conditions on the earth were quite different from what they are now, the present rule that life never arises save from pre-existing life, did not hold, and that the first life was evolved from lifeless matter. If so, evolution has given us progress indeed! But even if not so, there has been advance enough. Out of the blind and often cruel forces of Nature has come progress; and one of the final results of progress is to make possible in an increasing degree the substitution of the quick methods of consciousness and intelligence for slow chance, and of co-operation and the mitigation of suffering for universal struggle and cruelty.

It is true, in Matthew Arnold's words, though perhaps not quite in the sense which he intended, that there exists "a Power, not ourselves, that makes for righteousness," and that power is the sum of the forces of Nature, which have pushed life slowly and painfully onwards towards the righteousness of progress—of more life, more power, more mind.

Chapter VI

Nature and Nurture

FIFTY years ago it was the fashion to put down most of the shortcomings of human nature to environment. If but education were more copious and more excellent, we should all be both intelligent and moral; if we could only get rid of slums, we should be going most of the way towards abolishing crime. To-day there is a movement in the opposite direction. We read of psychopathic temperaments which lead people into wrongdoing as inevitably as a duck's instincts lead it to water, of tendencies to virtue or to vice (alas, usually the latter !) entailed upon families like ancestral estates. The plain man may be well excused if he is sometimes a little puzzled.

The truth, as so often, is between the two extremes. No character or property of any organism is due entirely to heredity, or entirely to environment. Let me give an example. The terrible disease known as anthrax is caused by a special bacillus. The entry of quite a few of these bacilli into the system of a human being, through a scratch, for instance, is fatal. But upon a hen they have ordinarily no effect whatsoever. Fowls appear to have an inherited resistance to the disease. However, if you first immerse a fowl in cold water for an hour, and then inject your bacilli, she contracts the disease, and, what is more, dies of it. In other words, the inherited resistance is present only in certain environments.

This is true of any and every character. For an animal to develop at all, it must be placed within certain limits of temperature, of light, of chemical environment. Frog's eggs at too high temperatures develop into

tadpoles with double tails; treated with certain chemicals they grow up without eyes.

The easiest way of looking at the whole matter is to remember that when we talk of the influence of heredity or environment upon a particular character in a living thing, we are really thinking in terms of *differences* of characters, not of characters as such. For instance, it is not really true to say that blue eye-colour and brown eye-colour are solely due to inheritance; but it is true that the difference between blue and brown eye-colour is entirely hereditary—we can bring up two children in identical conditions, and the difference between their eye-colours will remain. On the other hand, in moderately fair people the difference between light, untanned skin and dark, tanned skin is due to environment. If you took two identical twins and brought one up in tropical sunlight, the other in London fogs, their identity of inheritance would not prevent a great difference in skin-colour between them. Other differences may be partly due to heredity, partly to environment. Size, for instance, is partly under the control of hereditary factors, partly influenced by food and exercise.

In any event, what all recent work in biology has clearly shown is this—that simple inspection is never enough; by means of inspection alone we can never decide how much of a particular character depends on nature, how much on nurture. Analysis and experiment alone can decide for us. The classical experiment which opened our eyes to this fact was that of the Danish botanist Johannsen on beans. Beans are self-fertilizing, and any strain which has been self-fertilized for a number of generations becomes automatically pure as regards its hereditary constitution. Apart from rare mutations, the hereditary make-up of such a strain must go on being identically the same from generation to generation. None the less, if you collect all the beans from a single plant of a pure strain, you will find a considerable variation in weight among them, the weight of the smallest being less than a third of that of the largest. In spite of this, if you sow very small and very large beans from the same parent, you will find that there is no difference between their progeny as regards

the average weight of the beans they produce. In other words, the difference in weight between the beans on one plant has nothing to do with heredity; it has been brought about entirely by environment. Some beans will get a richer supply of food than others, depending upon their position in the pod, the position of the pod on the branch, of the branch on the stem, and so on; and this brings about differences in growth. Such non-inherited differences are called modifications.

There may be, however, other differences in size due to heredity. If, for instance, we compare the weight of the beans produced by different strains, we find that the average weight for one strain may be quite different from that for another, even when they are sown in the same plot.

Now if we take, say, a thousand beans at random, which have been gathered from an ordinary garden plot, we shall find again a great variation in weight. But we shall be entirely unable to tell from our weighings how much of the differences we observe are due to differences between the hereditary constitution of the beans, how much to differences in the environment in which they have grown up.

This has a further consequence. If, in a mixed lot of beans, we select the heaviest to sow, generation after generation, we shall at first get a rapid increase in the average weight of the resulting beans. But after five or six generations we shall find that further selection of the heaviest beans has no effect. Why is this? The answer is plain: because all we have done is to select one particular pure strain out of an original mixture of strains; and within a pure strain, as we have just seen, differences are not inheritable. Now and again, however, we might find a sudden change in average weight that was inherited, even in a pure strain. Such changes are changes in the hereditary material itself, and are called mutations.

Furthermore, if we took plants of the same pure line and grew some of them always in rough ground, others in well-manured soil, we should find a constant difference in average weight of beans produced, but this difference would not be inherited, and would disappear as soon as

the two cultures were cultivated in identical conditions again.

The best way, perhaps, of thinking of the matter is this. The hereditary constitution sets the limits to the possibilities of the stock, and environment determines which of those possibilities shall be realized. We cannot grow figs from thistles any more than we can grow thistles from figs; but if we want to grow good figs, we must manure the fig-trees.

The hereditary constitution is thus merely the capacity to react with a given environment in a particular way. The next problem which presents itself is this: can one modify the hereditary constitution at will, or are rare and apparently spontaneous mutations the only changes which take place in it? It is, of course, widely held that the effects of use and disuse are inherited. However, there is, as yet, absolutely no proof of this, and a good deal of evidence to show that it is not true. For example, more than fifty generations of the little fly Drosophila have been bred in complete darkness, without the least effect on the structure of their eyes or their capacity for seeing when brought into the light again. That bird of hill-country, the Dipper, lives by the water; it can walk under the water, and even progress there by using its wings; it can swim like a duck; and yet in its structure there is not the least evidence of adaptation to aquatic life, such as, for instance, webbing on the feet. Its mode of life has *not* brought about appropriate changes in structure.

During the last few years a good deal has been heard of the experiments of Professor Pavlov. He stated that the offspring of mice which had been trained to come to food at the sound of a bell were able to learn to do the same in a much shorter space of time than their parents, and that this inherited improvement, due to training, became more marked in each generation. However, he has never given a full account of his experiment, and is understood now to be repeating it to see if there was not some mistake; and meanwhile two other workers have undertaken a similar experiment, and find no inherited effect of training whatever. It would, of course, be very convenient if such inheritance of training

did occur. Instead of having to learn our own language, we should speak it instinctively from the start; and presumably children, when they heard the school bell ring, would remember the lessons their ancestors had learnt!

There is, however, some evidence that the effects of certain treatments may be inherited. For example, the effects of lead poisoning, in the form of slight general deterioration, appear sometimes to be inherited. With some of the lowliest of microscopic animals, exposure for a short time to strong doses of a poison like arsenic occasionally causes an increased resistance to the poison, and this may be inherited. And there are a few other similar results.

In general, we may sum up the situation as follows: there is no evidence of the inheritance of the effects of use, of disuse, of training, or of learning; but there is some evidence to show that the hereditary constitution may, although only occasionally, be altered by direct exposure to poisons, to extremes of temperature, and simple agencies like these. It is at any rate impossible to suppose that the great majority of the delicate adaptations seen in living things could owe their origin to the inheritance of acquired characters.

When we reflect, this is seen to be really a matter for congratulation. For, unfortunately, there are more human beings being brought up in unfavourable than in good surroundings. Most children, even from the worst slum, if taken away and brought up in healthy conditions in the country, will grow into very fair specimens of humanity; and everybody knows what a splendid record the London regiments had in the War, in spite of the fact that a great many of the men came from the most unfavourable environments.

It is probably true, however, that not only the average physique of slum dwellers is somewhat low, but also their average inherited potentialities; but this is almost certainly not due to the effect of living generation after generation in slums, but to the fact that a considerable proportion of types that have inherited poor qualities have gradually drifted into slum conditions of living.

With man, the whole problem is further complicated by

the fact that what we may call social environment or tradition (in the sense of education, the various influences of home, of civilization, of one's country) plays a much larger part in moulding development in him than in any other organism. The same child which would grow up in one way brought up in England of the twentieth century would have developed quite differently in England of the tenth century, or in modern Russia. It is the prevailing tradition of a nation which largely determines what we call "national characteristics." For instance, the view held in England during the Napoleonic wars about the French character was very different from that held to-day. Or, again, the prevalent view of the typical German in the middle of last century was of a placid, philosophic pipe-smoker; whereas by 1914 it was that of a sabre-rattling militarist. It is quite impossible that changes in temperament like these could have been brought about in such a short space of time by changes in the hereditary constitution of the nation; but a national tradition may—and does—change very rapidly, and so mould what is inborn in the national temper into quite new forms.

To revert to the general question, it is, of course, true that a good environment will be of the utmost importance in preventing both disease, and, for instance, criminal actions. But it is none the less true that inherited tendencies do exist which make it easier for some people than others to catch certain diseases; easier for some than for others to fall into a life of crime. Samuel Butler, in his famous satire, *Erewhon*, described an imaginary society in which people went to moral doctors for moral lapses, and received the sympathetic condolences of their friends when they stole or committed forgery; but were ostracized for lapses from health, and severely punished if they caught cold or fell into consumption. And there is certainly a great deal to be said for the view that much catching and spreading of disease is really criminal, many criminal actions the inevitable result of inheritance.

We may sum up the whole question by saying that in order to develop the most perfect types of men and women we want both good inheritance and good environ-

ment. The best environment will not bring out good qualities in a child with really defective inheritance, any more than bringing up a dog in the National Gallery will develop in it a taste for high art; and there are, alas, too many instances of bad environment crushing or distorting inborn genius. Eugenics and Education are complementary, not antagonistic.

Chapter VII

The Evolution of Man

IT is really a very curious psychological fact that so much prejudice has been aroused by the discovery that man has evolved from an ape-like ancestor. For such an origin, of course, implies that man has *advanced* during his evolution; whereas, for instance, the beliefs of the ancients that men were descended from gods or demi-gods, or that in the beginning was a golden age, or indeed the literal acceptance of the story of Adam and Eve and the fall of man, all equally obviously imply that present-day humanity is degenerate. One would also imagine, especially in a democratic age, that what man is and may become would count for more than pride of ancestry. None the less, the view which took away the stigma of degeneracy and gave man knowledge of past progress and hope of future improvement was, when put forward, greeted with execration as being impious and disgusting.

The feeling is perhaps a semi-instinctive one, like that which makes us recoil from the sight of blood or causes a medical student to faint at his first operation. However, luckily for humanity, medical students make it their business to overcome these illogical feelings; and we, secure in the faith that what is true must always in the long run bring with it what is right, should make it our business to overcome this particular repugnance.

For there is no doubt of its truth. Either Nature is meaningless, and the appearances which she thrusts beneath our eyes are not facts at all but deliberate lies, or else man is more closely related to the existing anthropoid apes than to any other creature, and at one stage in his evolution had an ancestor who would have to be classified in the same group as they.

Apart from all the detailed correspondences in struc-

ture, which can be looked up in any book on evolution, there are extraordinary resemblances in behaviour and emotion, as shown to us in Professor Koehler's excellent book *The Mentality of Apes;* and there is the close similarity of blood revealed by the so-called precipitin test.

These depend on the following facts. When the blood of one animal is treated with the blood of some quite different creature, it gradually acquires the power of precipitating this particular foreign blood in coagulated form. For instance, if horse-blood be added to the blood of rabbits previously treated with horse-blood, precipitation occurs; while if pigeon-blood had been added, there would have been none. But if donkey-blood had been added, the rabbit-blood, if previously treated with horse-blood, would have precipitated nearly but not quite so much of it, while cow-blood would have produced a faint precipitation. The more nearly related the animal to that first used, the more precipitation there is. Treated in this way, human blood is found to be chemically more like ape-blood than it is to monkey-blood, and more like monkey-blood than it is to that of any other animal.

However, what I must chiefly concentrate on in this short talk is the actual evolutionary history of man so far as we can piece it together, rather than a recapitulation of the well-known evidences for its occurrence. I can only touch on it in broad outline; for details my hearers should go to books like Professor Elliot Smith's *Essays on the Evolution of Man* and Professor Sollas' *Ancient Hunters.*

Man is obviously a mammal; back in the remote secondary period the first mammal, risen to that estate by having acquired warm blood, a covering of hair, and the power to secrete milk, contained within itself all the potentialities of man as well as of all the other mammals that we know—sheep, dog, lion, horse, rat, whale, and all the rest.

The average mammal differs biologically from man in a number of particulars. In the first place, in intelligence; then in running on all fours, and so having the fore-limbs mere locomotor organs like the hind-

limbs, not free for grasping; and in using the sense of smell far more than the sense of sight. These, together with the very prolonged period of human childhood, and therefore of learning, are the most important distinctions.

The first step in the human direction, away from the ordinary four-footed and smell-guided mammal, would appear definitely to have been the adoption of life in trees by some primitive shrew-like creature. Life in trees means grasping hands and feet; it necessitates accurate gauging of distance and therefore the encouragement of sight; and it means agility and versatility of movement, which in its turn reacts to make a more active mind. The grasping hand came to be used not merely for grasping the branches, but also for holding food and bringing it to the mouth—something which does not exist in most ground-living mammals. This in its turn led to more accurate estimation of shape, by a combining of the impressions gained from touch and from sight. By these means much more thorough knowledge of objects can be obtained than by the most acute sense of smell; and all this reacted on the brain, for when the possibility of detailed knowledge exists, there will be a premium on the power of using it properly. These steps led up gradually to the evolution first of the lemur-like type, and then to that of the monkey type. From this, by increase of size, loss of tail, and considerable increase of intelligence, the true apes were evolved. The next great step was the reversal of the first—a descent from the trees to the ground again, but this time with at least semi-erect posture, and with fore-limbs adapted for examining and manipulating objects, and now free for the discovery and control of ever more of the environment. Add to this a gregarious tendency and the gradual loss of body-hair, and the ancestor of man was near the boundary which divides us from the rest of the animals.

There can be little doubt that while ancestral man was developing in an upward direction from the ape-like stage, the ancestors of the existing apes were moving in many respects downhill—living more and more in forests, tending to rely more on strength than on intelligence, becoming less instead of more gregarious. There

is, in spite of popular misunderstanding, no question of man being descended from any of the *existing* apes; man's sub-human ancestor was some creature less intelligent than man, which resembled the apes in being tailless, covered with fur, and with hand-like feet. It is interesting to note that baby and embryo apes are a good deal more like man than are the adults.

The final step was taken, and ancestral man became man indeed, when he became capable of true speech—that is to say, of designating objects with definite names, not merely using sounds to express states of emotion. A chimpanzee, or, for that matter, even a chicken, can express by special sounds or gestures the fact that it is hungry or afraid; but it cannot tell its fellows *what* it wants to eat, when what it wants is not there. This power of giving names to objects is probably just one aspect of what we call true reason—the power of framing concepts, of abstract thought. And with the attainment of this faculty, life reaches a new plane.

For all man's close resemblance to apes in structure, in instinct and emotion, in many details of behaviour such as laughing at a practical joke or whimpering when frightened, his mind as a whole, thanks to this faculty of reason and concept-formation (and to this alone), is extremely different. Let us never forget that to trace back a thing to its origin, though it may help us to understand it, is not to explain it in these lower terms. To trace back the first origins of religion to simple and primitive instincts such as sex-love and fear, as some psychologists do, is not to say that religion *is* sex and fear, and not an uplifting of the soul, any more than to trace back the origins of art to love of bright colours and of certain simple arrangements and patterns is to say that there is nothing more in any art than simple colours and patterns. And so with man's mind. To know that it originated from ape-mind is to be able to understand it far better than before; but it remains itself, remains the highest thing that we know.

The actual course of human evolution before the dawn of history is traced chiefly by the tools and ornaments left by man, but also, though to a much smaller extent,

by actual human remains in the shape of bones. Through these latter we know that in the early days of man's existence there were other species of man in existence—the Taungs man-ape, the ape-man of Java, the Heidelberg man, the Piltdown man, Neanderthal man—all of which have now become extinct, leaving the one species now existing, *Homo sapiens*. These extinct men were on the whole more ape-like than we, and represent so many unsuccessful side-lines in evolution.

From the evidence of tools, especially flint instruments, we can trace man's progress more in detail. First came the crude objects known as eoliths—flints that needed only a few rough chips to make them serviceable. Then, in the Old Stone Age, the flints were definitely shaped, but never polished. In the New Stone Age they were polished too; but, though bone was widely used, we get never a trace of metals.

Then began the age of metals, first with copper, then with bronze, and later still with iron; and with that we are at the beginning of recorded history. What is interesting is to find that progress becomes more and more rapid as time goes on. We may date the earliest known flint implement at something like half a million years ago. At least three-quarters, probably nine-tenths of that time had passed before man learnt to polish his flints. The age of bronze started perhaps ten thousand years ago, as apparently did the earliest agriculture. Practically all history is crowded into five thousand years, while the last thousand alone have been responsible for a whole host of fundamental inventions like printing, gunpowder, anæsthetics, mechanical transport, flying, wireless, and the control over bacterial disease. From man's first beginnings until the present, the rate of progress has been growing more and more rapid; and there are no signs that it is slackening now. Humanity is biologically still youthful.

Once the human type of mind originated, it brought with it speech and, as a result, permanent tradition, first by means of speech alone, then also by means of writing and later by printing. Through tradition man comes to differ fundamentally from all other organisms; for tradition provides a new method of inheritance

which simulates the inheritance of acquired characters and makes possible the passing on to later generations of the results of learning and of training. It is on tradition that the social environment depends, and what we call human progress has almost all been progress in our tradition.

This means that, while inborn capacity must have changed enormously while our species was evolving from its ape-like progenitor, there can have been next to no inborn change since that time. Not merely since the time of the Greeks, but probably for about fifty thousand years, the inherited constitution of the human type has been what it is to-day, and progress has consisted merely in the amassing of more knowledge and more power through accumulated tradition.

The fact that the human type has not changed for thousands of years is sometimes thrown up as an objection to the evolution theory; all that it implies, however, is that the potentialities of the existing human type are so vast that they have not yet nearly been exhausted. There is no reason whatever to suppose that human nature is not capable of true hereditary evolution, of altering its potentialities as well as adding to its achievements.

On the other hand, in spite of all our progress there can be no one who thinks that the present state of things is a good one, or at least that it might not be improved; and in my final talk I shall try to give some views as to what science can suggest in the way of biological betterment for the future.

Chapter VIII

The Hope of Betterment

WHEN we speak of human betterment, we usually think of improvement in the conditions of life. But there is another, more fundamental possibility—that of the betterment of the human type itself; and it is of that alone that I shall speak to-day.

Man is an organism whose later progress has depended almost entirely upon changes in tradition, not in hereditary constitution—upon new achievements, fuller realization of innate possibilities rather than upon improvement of those possibilities. There is no evidence for any upward change during the whole historic period (and probably for much longer) in the upper level of intellectual, artistic, or ethical possibility. Einstein has not a better—or worse—mathematical brain than had Newton; Darwin was not a better biologist than Harvey, any more than was Beethoven a finer musician than Bach, Rodin a better sculptor than Praxiteles, Fox or Wesley greater or less great ethical teachers than the Hebrew prophets, Kant possessed of greater philosophical abilities than Plato—or even Bernard Shaw a greater writer than Shakespeare! The general run of human nature and human capacity has remained the same for thousands of years.

This is probably because there has been little pressure of natural selection to force it upwards. As matters have stood in human history, selection has acted chiefly on the group—the tribe or nation—rather than on the individual; and indeed great originality has too often actually been a handicap to its individual possessor: it is only in very recent years that we have begun to think of encouraging even that special brand of originality necessary for success in scientific research. Further,

selection has worked largely on the traditions of a nation and what it has learnt, instead of directly on its hereditary constitution. For instance, in the late war we did not exterminate our enemies—which would indeed have been a grave disaster for mankind; but we did at least go some way to exterminating a certain tradition and outlook which had hold of the dominant sections of the German nation.

Meanwhile, however, the very growth of knowledge and power has had certain rather disquieting results on humanity's inheritance. In earlier centuries, though natural selection was not forcing up humanity's upper level, it was at least keeping up the average by cutting off those who fell below a certain standard. Our present knowledge of heredity makes it clear that all sorts of recessive characters may remain latent for generations, to crop out when the right mating occurs: it also shows us that new types may arise as new combinations of old characters; and finally, it has revealed that mutations, or apparently spontaneous changes in hereditary constitution, are, though rare, yet constantly occurring. Unfortunately, but naturally, the majority of mutations are likely to be harmful—for the simple reason that it is much easier for a random change in a complex mechanism like the body or the brain to throw it out of gear than to improve it; and further, most mutations are recessive. Thus most of the recessive characters that crop up as the result of certain matings, as well as most of the new mutations, are likely to be unfavourable. Feeble-mindedness, certain tendencies to insanity, various bodily abnormalities, albinism, lack of general resistance—the greater number of cases of these and of various other defects depend either on recessive factors or on new mutations.

In the more ruthless past such defects were grave handicaps to their possessors; to-day our increased sense of pity and our more elaborate organization impel and enable us to preserve such types. In the same way, we are now more and more preventing short sight, or defective teeth, or absence of resistance to various disease-germs, from being nearly such great handicaps to their possessors as once they were. The result is that

in so far as such defects depend upon heredity—and all the evidence goes to show that the bulk of them do so—we are allowing the proportion of defective stocks and of defective factors to increase.

In the second place, we have now not only to face the general population problem—the fact that the time is already in sight when the world will be full up with people—but the particular aspect of the population problem which depends on the different rates of multiplication of different stocks and different classes. Up till sixty or seventy years ago, apparently this did not occur: all classes had about the same fertility. But to-day the so-called upper classes, especially the professional classes, are markedly less fertile than the average, and the fertility increases as we go down the occupational or economic scale; until we find it greatest among the casual labourer class. The effective fertility of unskilled labourers is nearly twice as great as that of the professional classes. As a result, twenty per cent. of this generation will produce twenty-five per cent. of the next. Obviously, in so far as there are inherited differences between the classes, this differential fertility is altering the inherited constitution of the nation as a whole.

Now the extent of hereditary difference between classes has often been much exaggerated; none the less there seems to be no doubt that to some extent it does exist—that, in spite of great overlapping, the *average* of innate intelligence, for instance, is a little higher in the professional than in the labouring classes, because more intellectual capacity is required to pass the bar examination or the medical examinations than to become a journeyman carpenter or a miner, and therefore selection will be always at work. Or, again, that the *average* of the temperamental qualities we call grit and concentration will be a little lower in the class of casual labour than elsewhere, because of the inevitable tendency of those who lack such qualities to drift down into this class. Even if the differences are slight, it is a very serious thing if, as is the case at present, differential multiplication is on the whole making desirable characters both of intellect and temperament a little less abundant in each generation.

It is especially serious in the case of the feeble-minded, for most of whom there is no doubt of the hereditary nature of their defect, and who have a very high fertility. The only remedy for differential fertility which can at present be envisaged is the spread, *equally to all classes*, of some method of restriction of family, including under this term what is generally called Birth Control. It should not be forgotten that rapid increase can only be a temporary phase, and that within a few centuries at most the world will be full up. The alternatives then will be either increased struggle, increased hardship, and increased death-rate, or else some control, some voluntary limitation of size of family. In any case, in the present economic state of Britain, what is wanted is the abolition of differential fertility, less, however, by increasing the size of smaller families once more, than by reducing the large size of the families of the other classes. From this point of view, quite apart from the humanitarian aspect, the refusal of the Ministry of Health to allow information on Birth Control to be given in State-aided clinics is deeply to be regretted.[1]

It was the realization of detailed facts like these, on a background of the newly-discovered theory of evolution, which led Galton to start his great campaign for racial improvement, or *Eugenics*. Galton himself coined the word Eugenics to denote the science and art of race betterment, and it has now passed into every civilized language.

I wish I could spend more time on this important and much-neglected subject; but a quarter of an hour's talk can only serve as an introduction. I would recommend my hearers to pursue the subject in Professor Carr-Saunder's recent book on Eugenics in the Home University Library. Here we can only touch on certain broad conclusions.

First, it is certain that, within one country and class, the differences between different individuals are due far more to heredity than to environment. On the other

[1] It is interesting to note that in Holland, where a rational attitude has been adopted towards birth-control, the difference in fertility between different economic grades of society has largely disappeared.

hand, the differences between different classes are due only slightly, but still significantly, to heredity. Then the important fact has been elicited that talent and genius are not on the average associated with low physique, nor with special defects like epilepsy; they appear no more often than usual in stocks tainted with insanity, and far less often than usual in stocks in which feeble-mindedness prevails. Further, the important fact has emerged that special talent in one direction is on the average correlated with high general or all-round ability; while at the opposite end of the scale there is conclusive evidence that most insanity, most imbecility, and most feeble-mindedness depend on the bringing out of inherited traits, and not merely, or even mainly, on environment.

These are a few of the different kinds of facts on which the science of Eugenics rests. It remains to ask what influence they should have upon our outlook and practice.

Most important is it that there should be an intelligent public opinion on the subject. The popular mind at present associates the word Eugenics with the idea of universal State Control of marriages and of unwarranted interference by eugenic policemen with private affairs. This is a mere travesty.

The Eugenic idea flows inevitably from a realization of certain simple facts. First and foremost is the fact of evolution, the realization that the inherited capabilities of man have developed by slow upward progress from those of brutes, and that there is nothing whatever against the process being continued further in the upward direction. Next, the facts of inheritance, the realization that the inherited qualities of any stock are due to the definite units we call hereditary factors, some of which are good, others bad; and that hereditary change in a stock depends either upon a change in the proportion of the different factors or in the origin of new factors from old by mutation. And finally, the realization that at the present moment the average of the hereditary qualities of the nation is definitely if slowly being lowered, while in the past the pruning-knife of natural selection kept the stock up to standard.

The Eugenic idea which must take possession of any one who has fully grasped these facts is, it seems to me, as follows. That just as we ought to try to give every child which actually comes into the world the best possible environment and education, so we ought to try to ensure that the children who *are* to come into the world shall have the best possible constitution; and this can only be done by some control of the individual's right to bring children into the world.

When Eugenists reach this point they are usually told that such methods are those of the stock-breeder, as if that settled the question. Those who use that argument seem to forget that the stock-breeder must and does combine favourable environment with good stock to achieve his results, and that to provide children with open air and play-grounds and healthy food is no more and no less a stock-breeder's method than is the attempt to provide them with a good inborn constitution.

The more serious objection comes from the possible interference with personal liberty. The utmost any responsible Eugenist would to-day propose in that direction, however, is that certain types of defective people should be prevented if possible from having children, and so from propagating the defect. Feeble-mindedness is as much a disease as is scarlet fever or small-pox. We do not allow a small-pox patient to propagate his disease by coming in contact with other people; on the contrary, we shut him up in an isolation hospital—and yet no one regards this as an unreasonable interference with personal liberty. There are round about 400,000 mentally defective persons in these islands. If we could prevent all of them from reproducing, the percentage of defectives would be about halved in four generations.

Reproduction can be stopped by segregating defectives in special institutions, or by artificial sterilization—an operation which is trifling for men, though rather more serious for women, while the psychological effects, again especially in men, are negligible. It may be of interest to recall that over two thousand people have already been sterilized for eugenic reasons in the United States.

The amount of personal suffering, social difficulty,

waste, and mere pecuniary loss inflicted on mankind by inherited factors which could be wholly or almost wiped out of the race by simple methods in a few dozen generations is prodigious. What anguish to have an imbecile child, or to know that one is oneself afflicted with the taint of insanity! What waste to spend millions on the education and care of the feeble-minded, if the result is merely a new generation of feeble-minded to care for and educate!

Nobody wishes to revert to the cruel methods of natural selection in earlier ages, in which most of the weak and defective were automatically killed off, nor to exchange these for other equally cruel methods of elimination. Pity is one of the highest virtues of civilized man. But what are we to think when pity for suffering individuals leads us not only to preserve them, but to allow them to reproduce and so not only to lower the quality of the race, but to produce more suffering in individuals yet unborn? What is one to think of the misplaced kindness which, to give an actual recent case, takes an epileptic woman to hospital to be operated on to remedy sterility; or the sentimentality which rejoices at the "happiness," so-called, generated by the marriage of two deaf-mutes?

The first thing for the people at large to realize is that some action is imperative. The second is for them to realize that our knowledge is still lamentably deficient in regard to the inheritance of many important human qualities. When they realize this, they will demand that the Government, through the Census or through a special department of State, such as that for Race-Biology recently established in Sweden, shall take steps to acquire the needed knowledge; and we can be sure that, once the facts are there and knowledge of them is widely diffused, action will follow.

Let us not forget that we men are the trustees of evolution, and that to refuse to face this problem is to betray the trust put into our hands by the powers of the universe.